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ENTITLED

ELECTRIC HYBRID VEHICLE

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ELECTRIC HYBRID VEHICLE

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. Application No. 10/194,745, which was filed July 12, 2002 and is pending, which is a continuation of U.S. Application No. 09/483,008, which was filed January 13, 2000 and issued as U.S. Patent No. 6,481,516, which is a continuation of U.S. Application No. 08/705,001, which was filed August 29, 1996 and issued as U.S. Patent No. 6,044,922, which is a continuation of Application No. 07/948,288, which was filed September 21, 1992, now abandoned, which is a continuation-in-part of Application No. 07/880,967 filed date May 8, 1992, now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to parallel electric hybrid vehicles and combined series-parallel electric hybrid vehicles, and in particular to the location of the component parts.

There are basically four types of electric propulsion systems known for vehicles. First, there is a pure electric drive vehicle. The pure electric drive vehicle has an electric motor which receives power from a main battery pack via a controller. The controller controls the speed of the electric motor. The major disadvantage of a pure electric drive vehicle is that the range is very limited and the vehicle must be stopped and connected to an energy

source such as an electrical outlet in order to be recharged.

The second type of electric propulsion system for vehicles is a series hybrid system. There are three major components in a series system: (1) a generator; (2) an electric motor arranged in series; and (3) an engine powering the generator. Mechanical energy generated by the engine is converted to electrical energy by the generator and is then converted back to mechanical energy by the electric motor. Each process of conversion is afflicted with losses and subsequent reductions of efficiency which is a significant disadvantage of this type of system.

The main advantage of the series hybrid is that it is possible to operate the engine at a fixed operating point within its engine speed/torque map. This point can be selected so that the engine functions with the greatest efficiency or produces particularly low emissions. Nevertheless, the efficiency of the entire series hybrid drive system is less than satisfactory.

The third type of electric propulsion systems is the parallel hybrid system, as described, for example, in U.S. Pat. No. 5,081,365. Parallel hybrid propulsion systems generally have three component areas: (1) electrical storage mechanism, such as storage batteries, ultracapacitors, or a combination thereof; (2) an electric drive motor, typically powered by the electrical storage mechanism and used

to propel the wheels at least some of the time; and (3) an engine, such as a liquid fueled engine (e.g., internal combustion, stirling engine, or turbine engine) typically used to propel the vehicle directly and/or to recharge the electrical storage mechanism.

In parallel hybrid systems, the electric drive motor is alternatively driven by mechanically coupling it to the engine. When coupled, the engine propels the vehicle directly and the electric motor acts as a generator to maintain a desired charge level in the batteries or the ultracapacitor. While a parallel hybrid system achieves good fuel economy and performance, it must operate in an on and off engine parallel mode. In this mode, the stop-and-go urban driving uses electric power and the engine is used to supplement existing electric system capacity. For long trips, when the battery for the electric motor could be depleted, the vehicle cruises on the small engine and the electric system will provide the peaking power.

The primary advantage of the parallel hybrid drive over the series drive previously described is improved efficiency (lower fuel consumption) in the engine, since the engine's mechanical energy is passed directly on to the drive axle. The bulky generator is no longer required, thereby lowering both the cost and weight of the vehicle.

However, with extended stop and go urban driving, the battery pack will be often depleted and

will need a charge in addition to the charge received from the electric motor. Or, the engine will be required to power the vehicle during the stop and go driving period thereby eliminating most beneficial effects of such an electric system. Therefore, the vehicle with a parallel system has limited inner city driving capabilities and range.

SUMMARY OF THE INVENTION

One embodiment of the present invention relates to a hybrid vehicle assembly. The assembly includes an electric motor/generator, an engine, a connection between the electric motor/generator and the engine, first and second electrical storage mechanisms, an energy conversion device and a voltage reducer. The electric motor/generator is operable as a motor and as an electrical energy generator. The first electrical storage mechanism is connected to the electric motor/generator for selectively powering the electric motor/generator. The energy conversion device is continuously connected to the engine. The voltage reducer is coupled to the first electrical storage mechanism, the energy conversion device and the second electrical storage mechanism so as to provide charge from the first electrical storage mechanism, the energy conversion device and the electrical energy generator to the second electrical storage mechanism.

Another embodiment of the present invention relates to a hybrid vehicle. The hybrid vehicle includes an electric motor, an engine, first and

second electrical storage mechanisms, a single energy conversion device and a voltage reducer. The electric motor and the engine are both drivably connectable to propel the vehicle. The first electrical storage mechanism powers the electric motor. The single energy conversion device is continuously coupled to the engine for providing a charging power output to the first electrical storage mechanism whenever the engine is running. The second electrical storage mechanism provides power to vehicle accessories at a lower voltage than the first electrical storage mechanism. The voltage reducer has an input coupled to both the single generator and the first electrical storage mechanism and has an output coupled to the second electrical storage mechanism to provide charging power at the lower voltage to the second electrical storage mechanism.

Another embodiment of the present invention relates to a vehicle assembly. The vehicle assembly includes an engine, first and second electrical storage mechanisms, an energy conversion device and a voltage reducer. The engine is drivably connectable to propel the vehicle assembly. The first electrical storage mechanism has a first voltage. The second electrical storage mechanism provides power to vehicle accessories at a second voltage, which is lower than the first voltage. The energy conversion device is continuously coupled to the engine and is coupled to the first electrical storage mechanism.

The voltage reducer has an input coupled to both the energy conversion device and the first electrical storage mechanism and has an output at the second voltage, which is coupled to the second electrical storage mechanism to provide charging power at the second voltage to the second electrical storage mechanism.

Due to the innate, but separate, advantages of both the series and the parallel drives, the above embodiments form combined series and parallel systems. In one embodiment, the engine has an alternator or generator connected directly to the engine's drive shaft by some mechanism, for example, a fan belt. Generally, alternators or generators are used to charge the battery of a vehicle's accessory systems, such as the lights, fans, etc. These systems typically operate on twelve (12) volts. However, the inventor of the present invention realized that the alternator is very capable of high current/high voltage output, ranging from, but not limited to, approximately ten (10) volts to in excess of one hundred fifty (150) volts. In standard applications, such as vehicle accessory systems, voltage output is regulated to approximately fourteen (14) volts. Implementation of some embodiments of this invention allows for efficient usage of the upper limits of the alternator's output capacity. Voltage output can be controlled by a central process controller, which directs excess current to the parallel system

vehicle's main storage battery pack. Voltage output can be varied to the appropriate levels by regulating the field current, among other methods of control.

The alternator can be set to a continuous high voltage level, matching that of the hybrid's main battery pack. A switching power supply could then channel generated current into the main battery pack, or into the vehicle's twelve volt battery. The switching power supply has the ability to reduce voltage to the appropriate level, based upon which electrical system is being fed. Alternatively, the power supply can be configured as a voltage reducer to reduce the voltage output from the alternator for the vehicle’s twelve-volt battery.

This arrangement eliminates the main disadvantage of conventional parallel hybrid designs as used in a vehicle. It has been found that at slow speed, such as stop and go urban driving, the parallel system will allow the main storage battery pack to deplete its energy below a comfortable and usable level of charge. A series hybrid system is more adaptable to urban driving because it constantly funnels limited amounts of electrical energy back into the system's battery pack. The main negative of a series hybrid system is that it does not permit an adequate charging level to sustain the high energy demand associated with long term, high speed driving. The above-embodiments of the present invention prevent depletion of the battery pack by better

utilizing the existing component structure typically associated with parallel hybrid systems.

Prior hybrid propulsion systems were capable of operating in one or more of the following modes, but not necessarily in all of them: (1) a series hybrid, which is plugged in for recharge, and which uses the engine as a "range extender" when the electrical storage mechanism is depleted, and/or (2) a series hybrid which runs the engine in order to recharge its own electrical storage mechanism, typically via a generator/alternator, and/or (3) a parallel hybrid, which is plugged in for recharge, and which uses the engine and/or the electric motor either separately or in unison, depending upon conditions, circumstances, and the process controller, in order to directly power the vehicle, and/or (4) a parallel hybrid similar to the one described in (3), directly above, but which recharges its own electrical storage system via the engine and, typically, a generator/alternator (see U.S. Pat. No. 5,081,365). Each of these modes has its benefits and drawbacks, depending on circumstances, thus the industry is involved in debate over which system is the most promising.

The purpose of the series-parallel functionality is to overcome problems inherent to either concept when employed individually. The advantages are increased range in the urban driving mode and a secondary method of range extension in highway mode without significantly increasing the bulk or cost of

the base parallel system. In addition, the control of the operation of the drive motor is more versatile and efficient.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of the power train and the controls for a series-parallel vehicle;

FIG. 2 is a block diagram of the power train and the controls for a vehicle incorporating an additional embodiment of the series-parallel vehicle; and

FIG. 3 is a block diagram showing the relative location of the electric and internal combustion motors in relationship to the vehicle, according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is an embodiment usable with the present invention. FIG. 1 illustrates in block diagram form an electric parallel hybrid vehicle power train and controls. An example of an electric hybrid vehicle power train is described, for example, in U.S. Pat. No. 5,081,365 which was patented by an inventor of the present invention and which patent is incorporated herein by reference.

The parallel hybrid system 10 includes a battery pack 18, an electric drive motor 16 powered by the battery pack 18 and an engine 24. A process controller 22 determines the prime mover of the vehicle, i.e., whether the electric motor 16 powers the vehicle, or the engine 24 drives the vehicle, or

both the electric motor 16 and the engine 24 drive the vehicle.

The electric hybrid power train and its related controls 10 includes ground engaging wheels 12. The wheels 12 could be either the rear wheels or the front wheels of the vehicle. In addition, it is within the scope of the present invention to have the drive wheels be part of a four-wheel drive system or a three-wheel tricycle. Only one drive wheel is necessary.

The drive wheels 12 are connected by a drive axle 13 to a differential 14, the housing of the differential 14 being attached to a housing of a transmission (not shown). The transmission is controlled in a conventional manner by a gear shift lever (not shown) and a foot-operated clutch such as the foot-operated 48 clutch shown in FIG. 3. The foot-operated clutch, gear shift lever, transmission, differential 14, drive wheels 12 and manner of connecting the drive wheels 12 to the differential 14 are conventional to a standard motor vehicle.

As mentioned above, the electric hybrid power train 10 includes an electric motor 16 which is one of two prime movers of the vehicle. The electric motor 16 is preferably a 40 HP 96-volt permanent magnet or compound wound DC motor.

The 96-volt battery pack 18 preferably consists of eight (8) 12-volt batteries in series is connected to the electric motor 16. If desired, a conductor

plug (not shown) may be connected to cross the battery pack 18 to connect the batteries in the battery pack 18 to an off-board battery charger. Such a mechanism for recharging the batteries may be desirable at times, though under most conditions, it will not be needed due to the on-board charging capability of the present system, as described below.

The 96-volt motor 16 and 96-volt battery pack 18 are not the only type that could be used. Indeed, a higher voltage motor and battery pack could give advantages in component weight and efficiency. It should be noted that the motor size and battery capacity are parameters that would in fact vary with the chosen vehicle weight and size.

A transistorized motor speed controller 20 is positioned between the electric motor 16 and the battery pack 18 and controls the current flow to the electric motor 16. The motor controller 20 is the link between the process controller 22 and the electric motor 16. The process controller 22, as described above, signals the motor controller 20 which disengages the current flowing from the battery pack 18 to the electric motor 16 or creates a generator from the electric motor 16 to charge the battery pack 18.

The motor controller 20 as used in one embodiment of the present invention can be a commercially available pulse width modulation type such as, for example, one made by Curtis PMC of

Dublin, Calif. The motor controller 20 regulates an array of parallel power MOSFET transistors to vary the average current to the electric motor 16 in response to a signal from the process controller 22.

At 24, is illustrated an internal combustion engine, which is the second prime mover of the vehicle. The engine is located in the end of the vehicle opposite the electric motor 16 as shown in FIG. 3. The engine 24 is preferably a 16-hp diesel engine, but it could be a spark ignition engine, turbine, or any other practical prime mover. For convenience in this discussion, it will be referred to as a diesel engine.

During acceleration of the vehicle, it is preferred that only the electric motor 16 drives the wheels 12. An electric clutch 26 positioned between the electric motor 16 and the engine 24 will allow the engine 24 to assist in driving the wheels 12 if the process controller 22 determines that the electric motor 16 needs assistance. Basically, such a situation arises if the process controller 22 determines that the electric motor 16 is not capable of accelerating the vehicle, such as accelerating up a steep incline. If such is the case, the process controller 22 will cause the engine 24 to be brought on line, as described below, to assist in driving the vehicle. While the engine 24 will assist the electric motor 16 if needed, it is not desirable to use the engine 24 in this fashion since accelerating the

vehicle with the engine 24 burns much fuel thereby decreasing fuel economy and increasing potential pollution.

After the vehicle has accelerated using the electric motor 16 and the electric motor 16 reaches a predetermined speed (rpm) without the assistance of the engine 24, the process controller 22 will cause the engine 24 to start or rev to get the engine 24 to approximately the same speed as the electric motor 16, i.e., within 1% of the electric motor's rpm. Once the engine 24 achieves the required approximately equal rpm, the electric clutch 26 activates such that the engine 24 also drives the wheels 12. While the electric motor 16 remains on line to drive the vehicle, the electric motor 16 is generally not needed in this capacity. Therefore, the process controller 22 switches the electric motor 16 into a generator. The process controller 22 controls the amount of current the electric motor 16 is capable of putting out and in that time puts energy back into the battery pack 18. For example, during an acceleration up to approximately 40 to 50 m.p.h. on the electric motor 16 only, it will take approximately 1 1/2 to 2 minutes to put that energy back in the battery pack.

If at any time during the driving of the vehicle, after the acceleration period, the process controller 22 senses that extra power is needed to maintain a constant speed, such as accelerating to

pass or climbing a steep incline, the process controller 22 will signal the motor controller 20 to activate the electric motor 16 to assist the engine 24. Basically, if the process controller 22 determines that the engine 24 needs additional power or rpm, the electric motor 16 is brought on line to assist in driving the wheels 12. In a standard vehicle, if the foot pedal is depressed to a certain point, the speed of the vehicle will be directly dependant on whether the vehicle is on a flat surface or an incline. With the vehicle of one embodiment of the present invention, if the foot pedal is depressed to a certain point, the speed of the vehicle will be at a certain predetermined speed, regardless of whether the vehicle is travelling on a flat surface or an incline. Therefore, if the engine 24 is not capable of maintaining the speed of the vehicle, the process controller 22 will activate the electric motor 16 to assist in driving the vehicle. Once that extra assistance is no longer needed, the process controller 22 will signal the motor controller 20 to cease the supply of electricity coming from battery pack 18 to the electric motor 16 and cause the electric motor 16 to operate as a generator to charge the battery pack 18.

Preferably, the electric clutch 26 is of any type which is capable of being engaged or released at will such as an AT clutch by Warner Electric, a subsidiary of DANA. When engaged, the electric clutch

26 couples the engine 24 to the input shaft of a transfer case (not shown), which is preferably a belt drive, but may be a gear or chain drive. Space permitting, the output shaft of the engine 24 could be aligned with the shaft of the electric motor 16 and the electric clutch 26 could selectively couple the engine 24 and the electric motor 16 directly without any need for a transfer case.

It will also be understood that requirements of available space in the vehicle might dictate some other configuration for selectively coupling the engine 24 to the electric motor 16. For example, a third shaft with a transfer case on each end of the shaft might be needed. It is within the scope of the present invention to cover any configuration required, so long as the engine 24 is coupled to the electric motor 16, through mechanism which may be engaged to release at will. The electric clutch 26 is a preferred device for this purpose due to the ease of controlling it, but other mechanism could be employed, such as a centrifugal clutch and pneumatic clutches.

The engine 24 is equipped with and drives an alternator 28, such as a Motorola 150A alternator DC power unit which is capable of high current/high voltage output, ranging from but not limited to, approximately 10 volts to an excess of 150 volts. In standard applications, such as vehicle accessory systems, voltage output is regulated to approximately

14-volts. The 14-volt output of the alternator 28 charges an accessory battery 30 which may be a single heavy duty 12-volt automotive battery. A group of accessories, which the accessory battery 30 controls and powers, includes such conventional automotive equipment as horn, lights, windshield wiper, etc. In addition, engine 24 also has a conventional starting motor (not shown) activated by a starter solenoid and powered by the accessory battery 30.

In accordance with one embodiment of the present invention, the alternator is additionally connected to the battery pack 18. In order to charge the battery pack 18, the voltage output of the alternator 28 must be compatible to charge the battery pack 18. Therefore, the process controller 22 includes a regulator control 34 which controls the voltage output of the alternator 28. The regulator control 34 adjusts the voltage of the alternator from a voltage compatible to charge the accessory battery 30 to a voltage compatible to charge the battery pack 18 and back to the voltage compatible to charge the accessory battery 30. Typically, the voltage compatible to charge the battery pack 18 is substantially greater than the voltage compatible to charge the accessory battery 30.

The regulator control 34 is actually part of the process controller 22 such that when the accessory battery 30 is completely charged, the process controller 22 will initiate the regulator control 34

to adjust the voltage upward and charge the battery pack 18. As mentioned, the battery pack 18 has a typically much higher voltage than that of the accessory battery 30. The voltage output of the alternator 28 is adjusted by the regulator control 34 to match the requirements of the accessory battery 30, which receives the highest priority in the voltage flow hierarchy as will be described below. Excess capacity, already at a compatible higher voltage level, is then made available to the battery pack 18 on a secondary priority level.

In the preferred embodiment, the actual switching of the voltage path from the alternator 28 to the accessory battery 30 and the battery pack 18 is accomplished through a switching mechanism 32. The switching mechanism 32 is positioned between the alternator 28 and the accessory battery 30 and the battery pack 18. The switching mechanism 32 receives signals from the process controller 22 directing the voltage output of the alternator 28 to either the accessory battery 30 or to the battery pack 18 depending on the signal from the process controller 22.

In the preferred embodiment, the alternator 28 will have a voltage output of approximately 14-volts when charging the accessory battery 30 and a voltage output of approximately 90-volts when charging the battery pack 18. Once the accessory battery 30 has been completely charged, the process controller 22

will increase the voltage output of the alternator 28 and will also signal the switching mechanism 32 to switch the path of the voltage from the accessory battery 30 to the battery pack 18. Thereafter, the voltage output of the alternator 28 will be directed to the battery pack 18 until the accessory battery 30 requires recharging. Thereupon, the process controller 22 will alter the voltage output of the alternator 28 to a suitable lower voltage and signal the switching mechanism 32 to begin directing the voltage to the accessory battery 30. This process will occur until once again, the accessory battery 30 is completely charged.

Another embodiment of the present invention is referred to in FIG. 2. For ease of understanding, like elements will be referred to with like reference characters.

As best illustrated in FIG. 2, the voltage output from the alternator 28 would be directed directly into the battery pack 18. In this embodiment, the process controller 22 and the switching mechanism 32 are not required. The voltage output would be preset at an approximate constant amount. A power supply 36 connected to receive some of the output voltage of the alternator reduces that portion of the voltage output of the alternator 28 such that the accessory battery 30 would also receive a compatible voltage.

FIG. 3 illustrates the specific location of the electric motor 16 and the combustion engine 24 with respect to the vehicle. The internal combustion engine 24 is located in one end portion 38 of the vehicle. The engine 24 is joined to a small diameter composite drive shaft 40 such as the one described sold by H and R Composites, Inc. as described above, which is incorporated herein by reference. The drive shaft 40 is connected to the electric motor 16 via the fly wheel 42 and the electric clutch 26. The electric motor 16 is located in the end portion 44 of the vehicle opposite the end portion 38. Note the end portion 44 may be the front portion of the vehicle where motors are located in standard vehicles or the end portion 44 may be the area where the trunk is located in standard vehicles. Additionally, the vehicle may be front wheel or rear wheel drive regardless of whether the electric motor 16 is in the front or rear end of the vehicle. Preferably, the electric motor 16 is located in the front of the vehicle when the vehicle has front wheel drive and in the rear of the vehicle when the vehicle has rear wheel drive. Thus, either the wheels 12a or the wheels 12b may be the drive wheels. The electric motor 16 is connected to a transaxle 46 via a foot operated clutch 48. The transaxle 46 may be a four-speed transaxle.

The design shown in FIG. 3, provides several distinct advantages. The design has little mechanical

complexity, provides spacing between the component parts, and allows easy access to the component parts. These features simplify manufacturing and maintenance work. The design also teaches a system that can be adapted to almost any internal combustion engine in any car. The design provides good weight distribution in the vehicle. And the design uses a light weight drive shaft, to help minimize the overall weight of the vehicle.

It can be seen that any series hybrid or parallel hybrid vehicle can be adapted to use the preferred embodiment of the present invention. First, regardless of the hybrid type, a high voltage alternator can be placed (or may already exist) in the vehicle. The high voltage alternator is then connected to the battery pack of the electric motor. A voltage reducer can be connected to the accessory battery to prevent the accessory battery from receiving an incompatible voltage. Then, so long as the engine is running, the battery pack will be recharging always ready to supply electric power to the electric motor regardless of whether a motorist is driving in the city or on the open highway.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.